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In vitro comparison of cyclic fatigue resistance of heat-treated rotary nickel titanium TruNatomy and ProTaper Gold with non-heat treated ProTaper Universal on simulated extremely curved root canal

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***Abstract*---**Objectives: The objective of the study is to compare cyclic fatigue resistance of heat-treated rotary nickel titanium TruNatomy and ProTaper Gold with non-heat treated ProTaper Universal on simulated extremely curved root canal. Methodology: Thirty heat treated rotary nickel titanium (NiTi) files were used for analysis in this

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study. Ten NiTi files were distributed to each group with a size of 25 and taper of 0.04. Group A (control group): ProTaper Universal (PTU), Group B: ProTaper Gold F1 (PTG), Group C: TruNatomy (TN). The cyclic fatigue of the NiTi instruments were evaluated using a custom-made experimental setup. NiTi files were tested within simulated 90-degree curvature canal in a metal block until the files were fractured. Number of cycles to failure (NCF) was then measured for each instrument. The one-way ANOVA test and Post hoc Tukey test was performed as statistical analysis to compare the cyclic fatigue of different rotary file. $P < 0.001$ was considered statistically significant. Result: Group C (TruNatomy) showed the highest mean value which was statistically significant with Group A and Group B with $P < 0.001$. Conclusion: Trunatomy showed the highest NCF & superior cyclic fatigue in simulated 90^{o} curved canal than ProTaper Gold and ProTaper Universal.

***Keywords*---**Cyclic fatigue, Canal curvature, Heat treated rotary files, ProTaper Gold, ProTaper universal, TruNatomy.

Introduction

Cleaning and shaping are the critical step for every root canal. The separation of rotary instruments in root canals with severe curvature as a result of cyclic fatigue is a serious concern in the practise of endodontics. [(1)] The endodontic file is used to remove intracanal pulpal tissues, microbial biofilm, and toxic by-products, as well as to develop a continuously tapering canal while maintaining canal geometry, allowing for the delivery of irrigating solutions and intracanal medicaments, as well as three-dimensional root canal filling. [(2)]

Canals are often shaped with stainless steel hand files. However, the restoration forces of the files tend to restore the file to its original form when used in the construction of curved root canals, resulting in canal transportation. [(3)] The fact that the majority of root canals are curved exacerbates the problem, making preservation of the natural canal morphology critical for effective treatment. [(4)] The file fractures under cyclic fatigue due to repeated compression and tension strains at the canal's maximum curvature point. NiTi files are frequently used to shape root canals due to their increased flexibility, rapid and centering canal preparation, safer preparation of curved canals, enhanced cutting efficiency, and improved treatment success. [(3,5,6)] According to the literature, a number of factors, such as the alloy and geometry of the file, thermomechanical manufacturing, and motion kinematics, affect canal formation. [(7–11)]

TruNatomy (TN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland) is a file system that is made from 0.8 mm NiTi wire rather than the 1.2 mm NiTi wire used in most files, and then heat treated. TruNatomy is said to have a lower likelihood of separation because of its greater resistance to cycle fatigue and flexibility. [(12)]

The geometry of the ProTaper Gold file (PTG; Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) is quite similar to that of the ProTaper Universal file (PTU; Dentsply Maillefer, Ballaigues, Switzerland). Both files have a convex triangular cross-section and a progressive taper. PTG instruments, on the other hand, have undergone thermomechanical heat treatment, resulting in the creation of a file with sophisticated metallurgy. With higher temperatures, PTG instruments have a 2-stage transition, whereas PTU instruments have a 1-stage change. [13] [14] Since no other study is done to check the cyclic fatigue of the newer TruNatomy files at extreme curvatures, the aim of the study is to evaluate and compare the cyclic fatigue resistance of the heat-treated file systems at simulated 90° extreme canal curvature in steel block.

Materials and Method

Methodology

Thirty selected nickel titanium files were used for analysis in this study of which, ten TruNatomy and ten ProTaper Gold NiTi rotary files were used which are heat treated with traditional ten ProTaper Universal NiTi rotary files which are non-heat treated.

1. Group A (control group): ProTaper Universal (PTU), size 25mm taper 0.04, n=10
2. Group B: ProTaper Gold (PTG), size 25mm taper 0.04, n=10
3. Group C: TruNatomy file (TN), size 25mm taper 0.04, n=10

Simulated canal in steel block

300 series stainless steel block (70 mm length 10 mm width) were used to simulate the artificial canal. Canal was milled by using diode laser (GIDC, Ahmedabad, Gujarat) with the aid of computer SOLID EDGE programme retained the instrument trajectory and replicated the instrument size and taper according to the settings chosen. The radius of curvature was set at 5 mm, with the angle of curvature remaining at 90°.

A custom-made experimental set up was used for evaluating cyclic fatigue of the NiTi instruments. The fixed shaping block had a radius of curvature of 5 mm and a constant degree of curvature of 90° and was made of concave, tempered steel. The endodontic files were mounted on an electric endomotor (NSK Endomate TC2, Japan) operated with a 16:1 reduction handpiece and the speed was set to 350 rpm with torque value of 1.2 N. The speed with which the crosshead of universal testing machine moved forward and backwards was set to 3 with a constant force of 2N.

Ten instruments in each group were tested within the simulated canals. Firstly, Group A, that is 10 files of PTU were mounted one by one followed by Group B (PTG) and Group C (TN). The fracture of the file was recorded in high quality video noting the seconds taken for the file to fracture. A single operator conducted the experiment. Number of cycles to failure (NCF) was then measured for each instrument with the following formula:

NCF Time taken for file to fracture (seconds) x Speed of Endomotor (rpm). Mean values were then calculated for each group and statistically analysed by using one-way ANOVA and Posthoc tukey test.

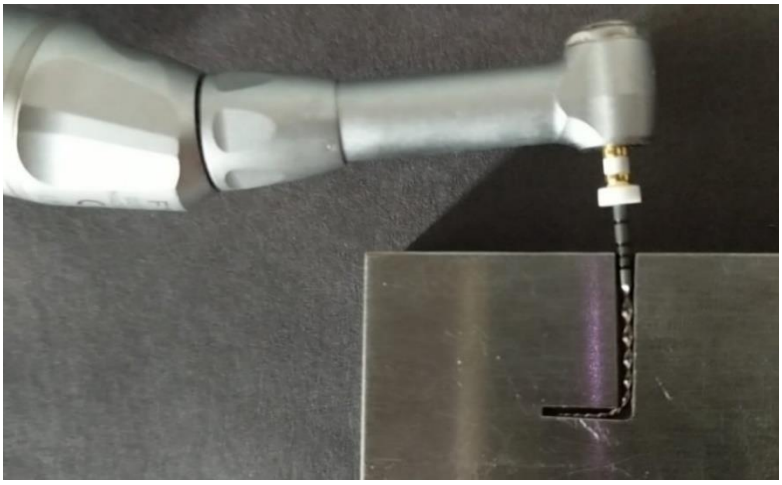


Fig 1: Experimental set up of the endomotor and metal block with 90^{o} curvature with ProTaper Universal file

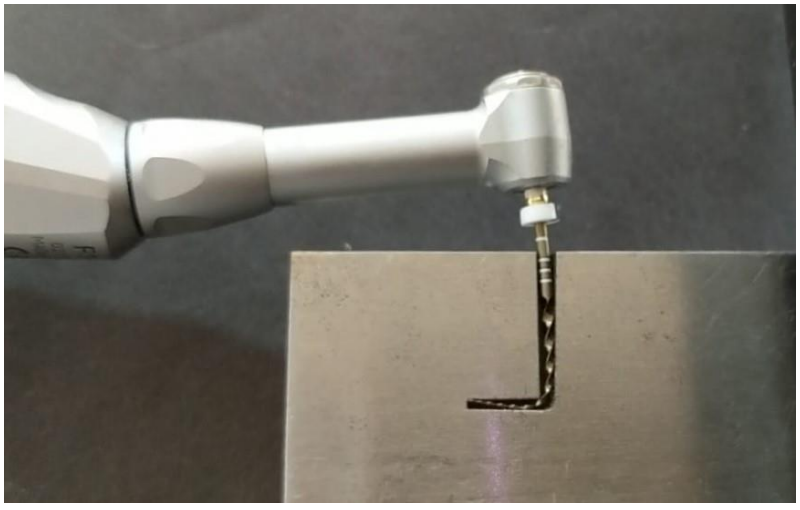


Fig 2: Experimental set up of the endomotor and metal block with 90^{o} curvature with ProTaper Gold file

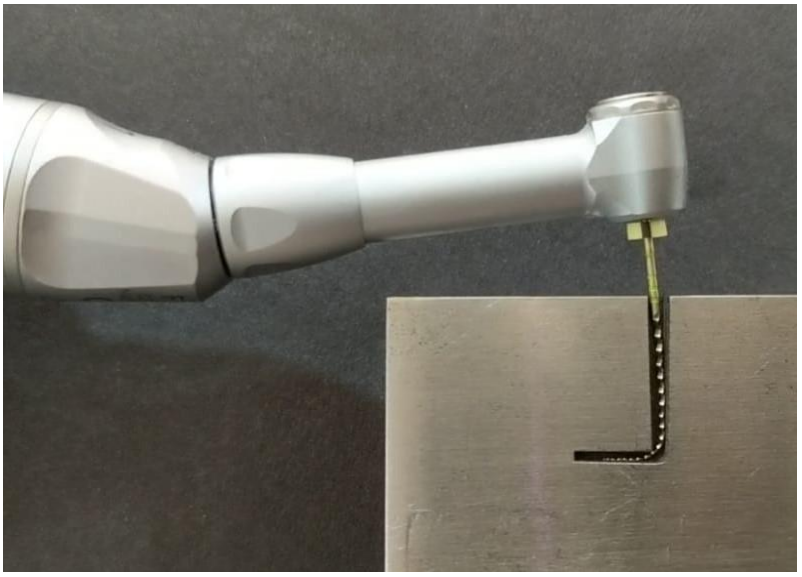


Fig 3: Experimental set up of the endomotor and metal block with 90° curvature with TruNatomy file

Statistical Analysis

The one-way ANOVA test and Post hoc Tukey test was performed to compare the cyclic fatigue of different rotary file system in simulated 90° curvature canal in steel block by using the SPSS version 20.0(SPSS Inc., Chicago, IL, USA). For numerical data, one-way analysis of variance (one-way ANOVA) was used to compare the means of three groups of samples (using the F distribution). To determine which of the three groups is responsible for the significant difference, a post hoc Tukey test was utilized. Statistics were deemed significant at $P < 0.001$.

Result

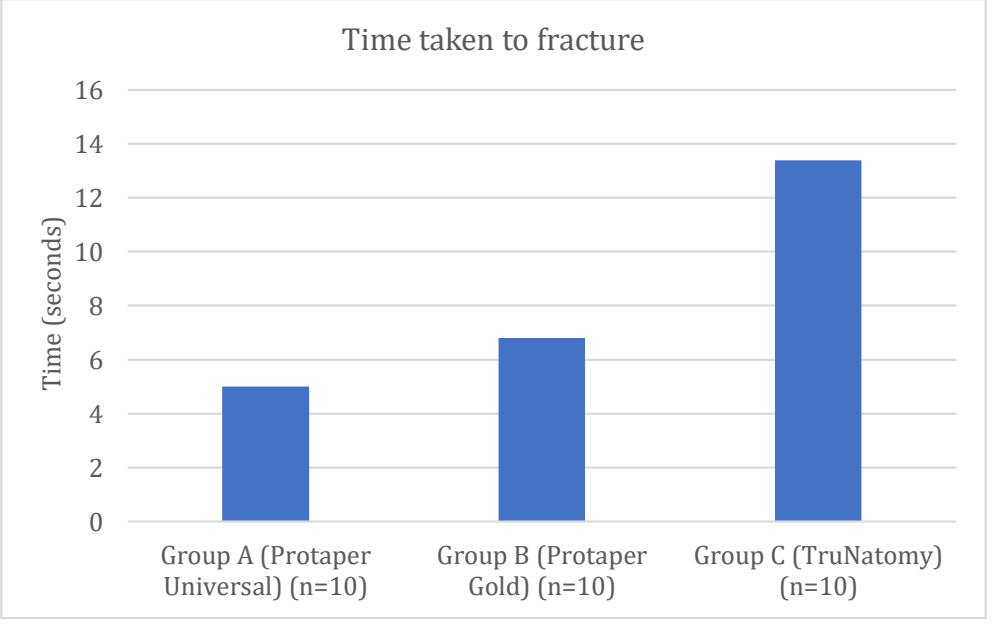
Within the limitation of this study, comparison of time taken to fracture between the three groups shows that Group C (TruNatomy) group has the highest value of 13.4 and Group A (ProTaper Universal) has the least value of 5. This difference is statistically significant with a test value of 528.12 and $P < 0.001$. Posthoc Tukey tests comparing Group C (TruNatomy) and Group B (ProTaper Gold) groups shows a mean difference of 6.6 and is statistically significant with a $P < 0.001$. Comparing Group C (TruNatomy) and Group A (ProTaper Universal) groups shows a mean difference of 8.4 and is statistically significant with a $P < 0.001$.

Comparison of cyclic Fatigue between the three groups shows that Group C (TruNatomy) group has the highest value of 4685 and Group A (ProTaper Universal) has the least value of 1750. This difference is statistically Significant with a test value of 519.305 and $P < 0.001$. Posthoc Tukey tests comparing Group C (TruNatomy) and Group B (ProTaper Gold) groups shows a mean difference of 2305 and is statistically significant with $P < 0.001$. Comparing Group C

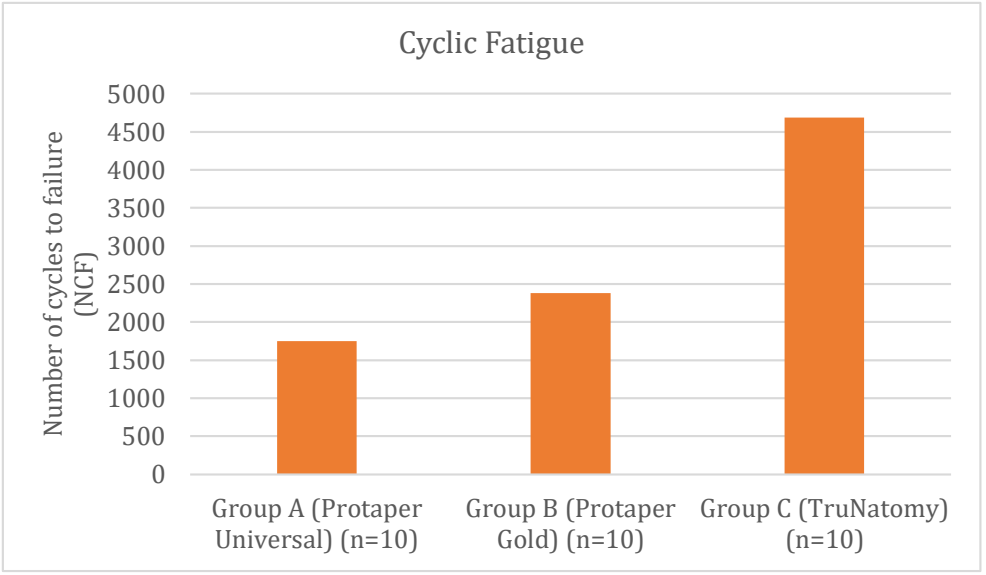
(TruNatomy) and Group A (ProTaper Universal) groups shows a mean difference of 2935 and is statistically significant with P <0.001.

Table 1: Comparison of the mean and standard deviations of the time to fracture in seconds and the number of cycles to failure (NCF) of the different systems tested in the present study at 90o curvature

	Group A (ProTaper Universal) (n=10)	Group B (ProTaper Gold) (n=10)	Group C (TruNatomy) (n=10)	One way Anova		Posthoc Tukey Test		
				F value *	P value	Group B (ProTaper Gold) vs Group C (TruNatomy) difference (p value)	Group A (ProTaper Universal) vs Group C (TruNatomy) difference (p value)	Group A (ProTaper Universal) vs Group B (ProTaper Gold) difference (p value)
Time taken to fracture	5±0.67	6.8±0.42	13.4±0.7	528.12	<0.001	6.6 (<0.001)	8.4 (<0.001)	1.8 (<0.001)
Cyclic Fatigue	1750±233.33	2380±147.57	4685±248.38	519.305	<0.001	2305 (<0.001)	2935 (<0.001)	630 (<0.001)



Graph 1: Graph showing the time taken for the file to fracture for each file



Graph 2: Graph showing cyclic fatigue of the file

Discussion

NiTi files have been created using a variety of techniques, which have improved clinical performance. These techniques include the application of specific surface coatings, ion implantation to create tougher surfaces, and electro polishing of machined surfaces. By changing the phases of the alloy, heat treatment can also improve the physical properties of NiTi. [15]

Due to variations in root canal morphology, it is not possible to choose genuine canals with the same curvature in terms of angle and diameter despite the fact that real teeth more accurately reflect clinical situations. [16] As a result, in the current investigation, stainless steel simulated canals rather than extracted teeth, as previously described, were used to standardise cyclic fatigue tests. [17] Extreme canal curvature of 90^{o} was used in this study because curved canals were found in 59 percent of the teeth, with the posterior teeth having a higher frequency than the anterior teeth. The most frequent root canal curvature was seen in the apical third section (53.9 percent), followed by the cervical (33.3 percent) and middle (12.8 percent) third sections. [17]

In this study, TN file system is used to check for its cyclic fatigue as the company claims that it is made from 0.8 mm NiTi wire rather than the 1.2 mm NiTi wire used in most files, and then heat treated. TN is said to have a lower likelihood of separation because of its greater resistance to cycle fatigue and flexibility. [18] There has been no significant variation in the respective sizes of the fractured segments across all groups, indicating that it tested instruments were properly positioned inside the canal curvature and that similar loads were created during the test.

The TN files had the highest mean NCF when compared to the other two groups. The TN's thermomechanical processing is made of a heat-treated NiTi wire, which may have helped increase their number of cycles to failure (NCF). When compared to PTG and PTU, which have equilateral triangle cross sections, the TN file has an off-centered parallelogram cross-sectional design [18], which may be a factor in the TN files' higher cyclic fatigue resistance. Furthermore, the thin NiTi wire (0.8 mm) used in the TruNatomy file may have boosted cycle fatigue resistance. [19]

PTG instruments were found to be substantially more resistant to cyclic fatigue than PTU devices. This finding is consistent with earlier research. This could be due to the fact that PTG and PTU instruments go through distinct production procedures, which could affect their fatigue resistance. The PTG instruments have been reported to have a two-stage transformation behaviour (austenite [A]-Rphase-martensite [M]) and high Af temperatures due to heat treatment. [19]

TruNatomy files showed enhanced cyclic fatigue resistance but there is certain limitation to this invitro study such as clinical considerations like the various curvatures which occur naturally in the tooth which cannot be simulated artificially in the metal block, effect of various irrigating solutions and effect of autoclaving cycles are yet to be discovered and future studies are required to evaluate other properties of this file.

Conclusion

The TruNatomy file showed a superior cyclic fatigue resistance compared with the ProTape Gold and ProTaper Universal file. ProTaper Gold is significantly more resistant to fatigue compared with ProTaper Universal.

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